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THE LARVAL DEVELOPMENT OF *CLIBANARIUS VITTATUS* (BOSC) (CRUSTACEA: DECAPODA; DIOGENIDAE) REARED IN THE LABORATORY[1]

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Published descriptions of the larval development of members of the Anomuran family Diogenidae are limited to sixteen species in seven of the fifteen genera (see Table I). In addition, Hale (1927) claims a direct development for *Cancellus typus*. *Calcinus verrilli* and six species of *Paguristes* have been reported reared by Provenzano (1968) and *Cancellus spongicola* has been hatched (Provenzano, personal communication), but these descriptions remain unpublished. No larval descriptions exist for species of the genera *Allodardanus, Aniculus, Isocheles, Loxopagurus, Paguropsis, Pseudopagurus,* or *Troglopagurus.* In the genus *Clibanarius* descriptions of the larvae of *C. erythropus* (Hesse, 1876; Issel, 1910; Boraschi, 1921; Bouvier, 1922; Carayon, 1942; Dechancé and Forest, 1958; Pike and Williamson, 1960a, b), an illustration of the larvae of *C. tricolor* (Lewis, 1960), and mention of larvae of unidentified species of *Clibanarius* (Czerniawsky, 1884; Menon, 1937) have been published. Provenzano (personal communication) has reared *C. anomalus, C. antillensis,* and *C. tricolor* but none of these descriptions has been published.

Clibanarius vittatus (Bosc) is a very common hermit crab species in intertidal and shallow estuarine water regions of the southeastern coast of the United States. Its known range is from the Potomac River, Gunston, Virginia to Rio de Janeiro, Brazil (Williams, 1965). Although the species has been successfully reared by Provenzano (personal communication) and larval stages have been reared and partially described by Kircher (1967) and Kurata (unpublished), a published description of the larvae of *C. vittatus* has not been completed. The following study was undertaken to provide complete descriptions of laboratory-reared larvae of *C. vittatus* to aid in accurate identification and staging of decapod larvae in field sampling or laboratory investigations.

Materials and Methods

On July 7, 1975 numerous specimens of *C. vittatus* were collected by hand from shallow water (temperature, 26° C; salinity 30‰) in the North Inlet estuary, Georgetown, South Carolina. The shells of the hermit crabs were carefully broken and several shell-less ovigerous females were isolated individually in 9 cm Carolina culture dishes containing filtered natural sea water of 25‰ salinity and maintained

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TABLE I

Published descriptions of larvae of Diogenidae.

Genus	Species	Author	Date	Material
Calcinus	*ornatus*	Pike and Williamson	1960b	all stages
	tibicen	Provenzano	1962	all stages
Clibanarius	*erythropus*	Hesse	1876	zoeal stage I only (as *Pagurus misanthropus*)
		Issel	1910	zoeal stage I only (as *C. misanthropus*)
		Boraschi	1921	zoeal stage I only (as *C. misanthropus*)
		*Bouvier	1922	megalopa only (as *Glaucothoe grimaldii*)
		Carayon	1942	megalopa only (as *C. misanthropus*)
		Dechancé and Forest	1958	megalopa only
		Pike and Williamson	1960a	zoeal stage I; megalopa
		Pike and Williamson	1960b	zoeal stages I, II, III
	tricolor	Lewis	1960	unspecified zoeae
Dardanus	*arrosor*	Issel	1910	zoeal stage I only (as *Pagurus arrosor*)
		Boraschi	1921	zoeal stage I only (as *Pagurus arrosor*)
		Bourdillon-Casanova	1960	zoeal stage I only
		Pike and Williamson	1960b	zoeal state I only
		Dechancé	1962	zoeal stage I only
		Kurata	1968a	all stages
	fucosus	Provenzano	1963b	megalopa only (as *Petrochirus diogenes*)
		Biffar and Provenzano	1972	megalopa only
	insignis	Provenzano	1963b	megalopa only
	scutellatus	Provenzano	1963b	megalopa only
	venosus	Provenzano	1963a	megalopa only
Diogenes	*pugilator*	Gurney	1927	all stages
		Menon	1937	all stages
		MacDonald, Pike and Williamson	1957	all stages
		Pike and Williamson	1960a	all stages
		Pike and Williamson	1960b	all stages
	varians (?)	*†Czerniawsky	1884	two zoeal stages only
Paguristes	*digitalis*	Kurata	1968b	all stages
	oculatus	Issel	1910	zoeal stages I and III; megalopa
		Pike and Williamson	1960b	all stages
	sericeus	Rice and Provenzano	1965	all stages
	turgidus	Hart	1937	all stages
Petrochirus	*diogenes*	Provenzano	1968	all stages
Trizopagurus	*magnificus*	Provenzano	1967	all stages

* Not seen by present authors.
† In Russian, extracts in Bouvier (1891).

at 25° C under a 15L:9D light schedule. At 1500 hours on July 8 one brood hatched, and 100 of the most active larvae were placed individually in 6 cm dishes containing 15 ml filtered natural sea water of 25‰ salinity and were maintained

TABLE II

Survival, development time, and duration of the larval stages of Clibanarius vittatus *(Bosc) reared in the laboratory.*

Stage:	Zoea I		Zoea II		Zoea III		Zoea IV		Zoea V		Megalopa	
July hatches:	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
Survival from first zoeal stage to indicated stage (percentage of original number*)			39	59	25	51	22	48	15	48	11	37
Survival within each stage (percentage of indicated stage to reach subsequent stage)	39	59	64	87	88	98	68	98	73	94	**	33
Time from hatching to reach each stage (days):												
range			8–11	12–17	13–17	19–29	19–24	25–35	25–29	33–43	33–36†	43–51†
$\bar{x}$			9.4	13.7	15.0	21.8	21.4	29.7	27.5	37.2	35.2	47.0
n			39	46	25	41	21	43	13	33	9	33
Duration of each stage (days):												
range	8–11	12–17	4–7	6–16	6–7	5–10	5–7††	6–9††	5–8	9–11		32–43
$\bar{x}$	9.4	13.7	5.7	8.3	6.4	7.9	6.3	7.7	7.8	9.9	**	36.3
n	39	46	25	35	21	39	13	34	9	30		3

* 100 for July, 1975; 90 for July, 1976.

** Experiment terminated—megalopae not allowed to molt to first crab.

† Values given for megalopa reached from stage V; for megalopa direct from stage IVb, 30 days (n = 2) for 7/75 and 39–47 days ($\bar{x}$ = 43.5, n = 6) for 7/76.

†† Values given for stage IVa; for stage IVb, 8–9 days ($\bar{x}$ = 8.5, n = 2) for 7/75 and 9–18 days ($\bar{x}$ = 13.7, n = 6) for 7/76.

under the conditions described above. Water was changed daily and two drops of concentrated freshly hatched *Artemia* nauplii (San Francisco Bay) were added following each water change.

Individual records were kept for each zoea to determine the number and duration of larval stages. Exuviae from each stage and larvae were preserved in 70% ethyl alcohol. Drawings were made from larvae and exuviae mounted in glycerine using camera lucida. Measurements of preserved larvae were made with an ocular micrometer. Total length (TL) and carapace length (CL) are as described by Pike and Williamson (1960b). Additional larvae were reared during July and August, 1976 to allow for measurements on a larger number of individuals and to check for variations between different broods.

Results

Four or five zoeal stages and a megalopa were obtained through rearing. Rearing in 1975 was terminated before the first crab stage was reached, while in 1976 megalopae were allowed to molt to first crabs. Although similar rearing techniques were used in both instances, the 1976 larvae generally had better survival and longer duration of larval stages. Overall survival values, times to reach each stage, and duration of each stage are summarized in Table II.

Measurements of CL and TL in *C. vittatus* zoeae and megalopa are presented in Table III. Of four hatches of *C. vittatus* measured at stage I, only July, 1975 and July, 1976 were reared. Of particular note is the size variation observed at stage I. Larvae of hatch August, 1975 are consistently larger than those of hatch June, 1976 while July, 1975 and July, 1976 are intermediate in size. As expected with this initial variation, size ranges of later zoeal stages often overlap.

Table III

Size ranges and means for carapace length and total length (in mm) of the larval stages of Clibanarius vittatus *(Bosc) reared in the laboratory.*

Stage	Hatch	Carapace Length			Total Length		
		Range	$\bar{x}$	n	Range	$\bar{x}$	n
Zoea I	July, 1975	0.9–1.1	1.0	15	1.9–2.2	2.1	15
	August, 1975	1.0–1.1	1.0	10	2.1–2.4	2.3	10
	June, 1976	0.9–1.0	1.0	10	2.0–2.2	2.1	10
	July, 1976	1.0–1.1	1.0	10	2.0–2.3	2.1	10
Zoea II	July, 1975	1.1–1.3	1.2	5	2.3–2.9	2.6	5
	July, 1976	1.1–1.2	1.1	10	2.2–2.7	2.5	10
Zoea III	July, 1975	1.5–1.7	1.6	4	2.8–3.5	3.3	4
	July, 1976	1.7–2.0	1.8	10	3.5–4.1	3.7	10
Zoea IVa	July, 1975	1.7–2.5	2.1	4	3.6–4.4	4.1	4
	July, 1976	2.0–2.5	2.2	10	3.8–5.0	4.4	10
Zoea IVb	July, 1976	2.3–2.6	2.4	4	4.4–5.2	4.8	4
Zoea V	July, 1975	2.6–2.7	2.6	3	4.5–4.8	4.7	3
	July, 1976	2.3–2.7	2.5	9	4.3–5.3	4.9	9
Megalopa	July, 1975	1.1–1.5	1.4	4	3.8–4.1	3.9	4
	July, 1976	1.3–1.4	1.3	3	3.2–3.7	3.4	3

The size of stage IV zoeae molting to megalopa (IVb) is greater than that for stage IV zoeae (IVa) molting to stage V. Size alone is not an adequate or reliable criterion for staging larvae of *C. vittatus*.

Pigmentation of larvae was not studied in detail since the bulk of the material was preserved for later examination and alcohol rapidly bleaches chromatophores in this species. Based on brief observations of freshly sacrificed zoeae, a general pattern is evident. Chromatophores are red or orange-red and present in all stages. Small chromatophores occur ventrally along the rostrum and at the bases of the antenna and antennule. Variable patterns of small chromatophores and a diffuse faint reddish color are found in the mouth parts. At least three distinct chromatophores are found on the ventrolateral carapace surface. The abdomen has a large dorsal chromatophore in each segment and some fine color spots on the ventral surface. A more critical study of pigmentation in *C. vittatus* may provide a useful characteristic for the identification of fresh material.

Descriptions and drawings of each stage follow. The present study has stressed setal numbers; when setal types are mentioned, terminology is based on

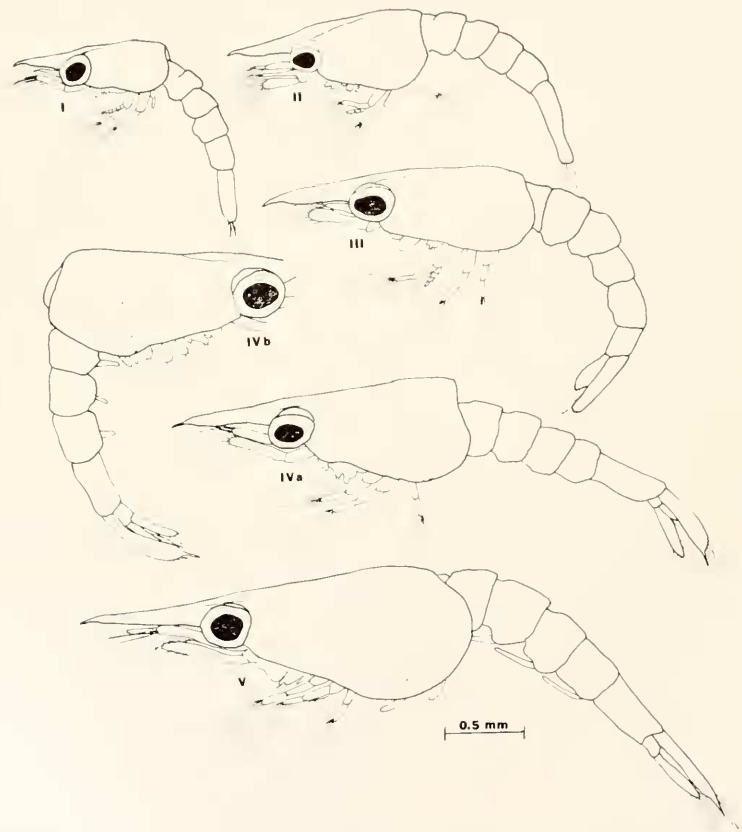

FIGURE 1. *Clibanarius vittatus:* lateral view of zoeal stages I–V. Stage IV zoeae may molt to stage V (IVa) or directly to megalopa (IVb).

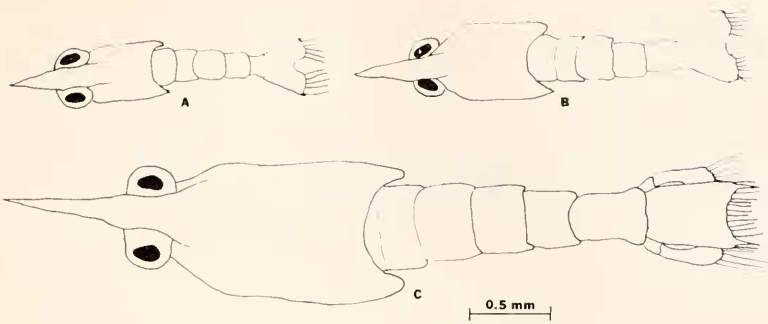

FIGURE 2. *Clibanarius vittatus:* dorsal view of zoeal stages I (A), II (B) and V (C).

that used by Bookhout and Costlow (1974). Abbreviations used are as in Roberts (1970).

Due to the individual variation and complex configuration of the mandibles, only two examples of the configuration and development of the palp are shown (Fig. 6). No attempt has been made to illustrate the mandibles for each stage.

Zoea I (Fig. 1, I, 2A)

The rostrum is long, extending beyond both the antenna and antennule and constricts to a short narrow tip curved ventrad. The carapace is without processes or spines; the postero-lateral border is smoothly rounded. Eyes are sessile. The abdominal somites are plain without spines; the sixth somite and telson are fused. The telson is bilaterally convex with a prominent median notch (Fig. 3A), The telson formula is $7 + 7$; process 1, a very short blunt spine; process 2, a short setose hair; processes 3–7, long plumose setae.

A1 (Fig. 4A): uniramous, unsegmented, with 3 terminal aesthetascs, 2–3 terminal plumose setae, and 1 prominent subterminal seta.

A2 (Fig. 5A): basipod with 1 short spinose spine; endopod about $\frac{2}{3}$ length of scale with 3, rarely 4, terminal setae; scale with 9–11 plumose setae.

Mn (Fig. 6A): large anterior conical tooth and complex array of smaller teeth and projections on biting surfaces; asymmetric, palp absent.

Mx1 (Fig. 7A): coxal endite with 6 setae; basal endite with 1 denticulate and 2 denticulate cuspidate setae and occasionally 1 short simple seta; endopod with no distinct segmentation, 3 plumose setae.

Mx2 (Fig. 8A): coxal and basal endites bilobed; coxal endite with 6 setae on proximal lobe, 4 setae on distal lobe; basal endite with 5 setae on proximal lobe, 3–4 setae on distal lobe; endopod with 2 terminal and 2 subterminal setae, fringed edges; scaphognathite with 4–6 plumose setae.

Mxpl (Fig. 9A): basis with 7–9 fine setae on inner margin; endopod 5-segmented, fringed on outer margin of segments 2–4, 1 plumose seta at distal margin of 4th segment 2, 2, 1, 2 fine setae on inner margin of segments 1–4; segment 5 with 3 denticulate setae and 1 simple seta terminal. Exopod with 4 terminal natatory plumose setae.

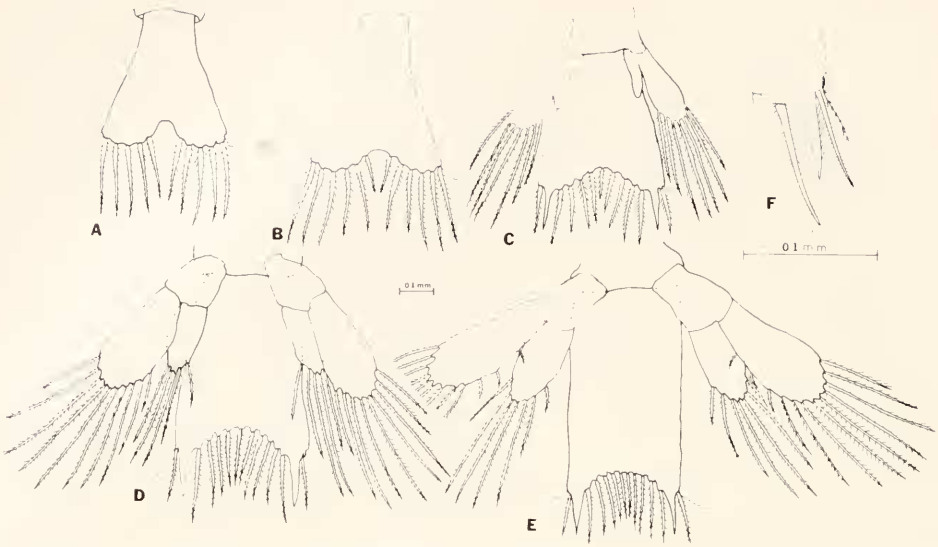

FIGURE 3. *Clibanarius vittatus:* telson of zoeal stage I (A), II (B), III (C), IV (D), and V (E). Detail of telson processes 1–5 (F) indicates pattern found in stages III–V.

Mxp2 (Fig. 10A): basis with 3 fine setae on inner margin; endopod 4-segmented, 2 fine setae each on inner margin of segments 1–3, segment 4 with terminal plumose or denticulate setae, 1 plumose seta on outer margin; exopod with 4 terminal natatory plumose setae.

Mxp3 (Fig. 10a): uniramous exopod without setae.

Zoea II (Fig. 1, II, 2B)

Except for size increase, the rostrum and carapace are as in stage I. The eyes are stalked. The telson has a shallow notch medially with convex lobes (Fig. 3B). The telson formula is 8 + 8; process 1, greatly reduced or absent (Fig. 3F); process 2, a short plumose hair; processes 3–8, plumose setae. Pleopod buds and uropods are absent.

A1 (Fig. 4B): uniramous, 2-segmented; peduncle with 3–4 long plumose setae and 0–2 short setae at base of distal segment; distal segment with 2 terminal aesthetascs, 2–3 terminal fine plumose and 2 subterminal aesthetascs.

A2 (Fig. 5B): basipod unchanged; endopod with 4 setae; scale with 11 plumose setae.

Mn: increase in size and number of smaller teeth.

Mx1 (Fig. 7B): coxal endite with 6 setae; basal endite with 4 denticulate cuspidate setae, 1 short plumose seta and 1 very short simple seta; endopod with 3–4 plumose setae.

Mx2 (Fig. 8B): coxal endite with 6–7 setae on proximal lobe, 3–4 setae on distal lobe; basal endite with 4–5 setae on proximal lobe, 3–4 setae on distal lobe; endopod unchanged; scaphognathite with 7 plumose setae.

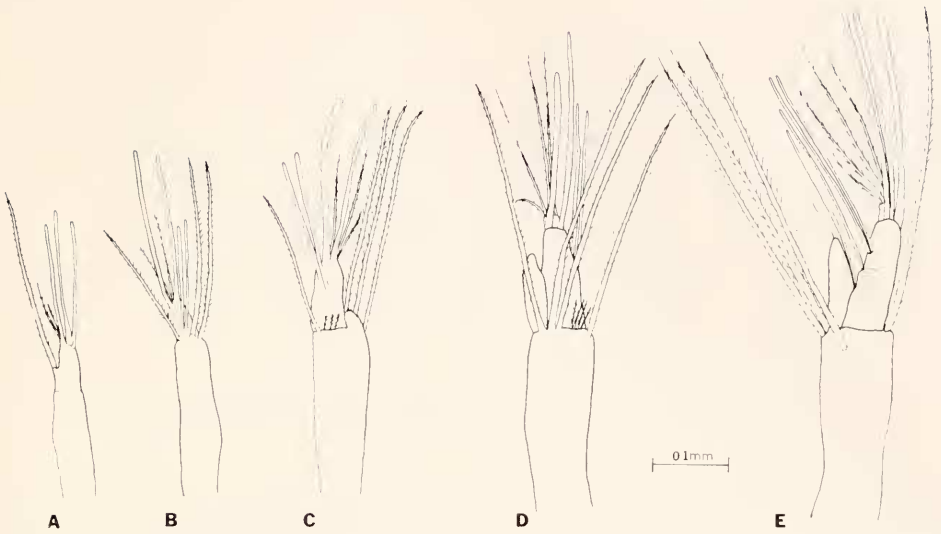

FIGURE 4. *Clibanarius vittatus:* antennule of zoeal stage I (A), II (B), III (C), IV (D), and V (E).

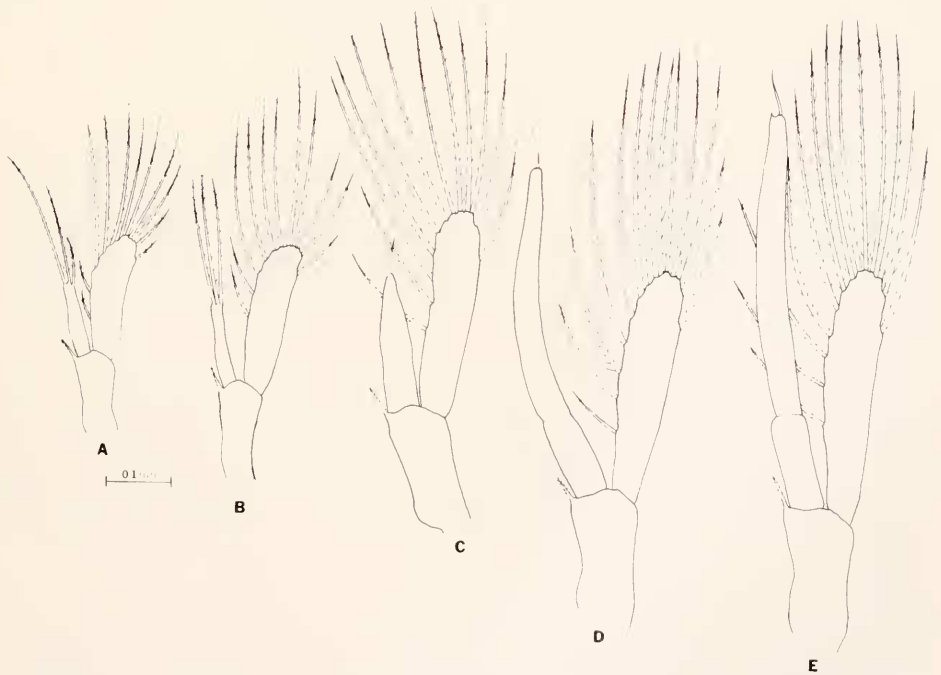

FIGURE 5. *Clibanarius vittatus:* antenna of zoeal stage I (A), II (B), III (C), IV (D), V (E).

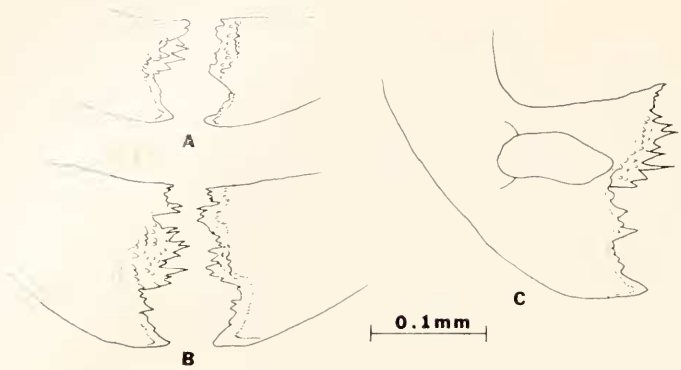

FIGURE 6. *Clibanarius vittatus:* mandibles of zoeal stage I (A), III (B) and anterior view of zoeal stage V (C).

Mxpl (Fig. 9B): basis unchanged; endopod 5-segmented, 1 seta on outer margin of each segment 1–4, 2, 2, 1, 2 fine setae on inner margin of segments 1–4, segment 5 with 3 denticulate setae and 1 simple or denticulate seta terminal; exopod with 6 terminal natatory plumose setae.

Mxp2 (Fig. 10B): basis with 4 fine setae on inner margin; endopod 4-segmented, 2 fine setae on inner margin of each segment 1–3, 0, 1, 1, 1 setae on outer margin of segments 1–4, segment 4 with 4 terminal serrate or denticulate setae; exopod with 6 terminal natatory plumose setae.

Mxp3 (Fig. 10b): uniramous with 5, sometimes 4, terminal natatory setae.

Zoea III (Fig. 1, III)

The rostrum and carapace remain unchanged. An articulation between the sixth abdominal somite and the telson first appears. Uropods (U) present with exopod and endopod fused. Pleopod buds are usually absent or very rudimentary. The posterior margin of the telson is concave with no notch or bilateral lobes (Fig. 3C). The telson formula is 8 + 1 + 8; process 1, a small stub, process 2, a plumose hair; process 3 a plumose seta; process 4, a fixed spine; processes 5–8 and medial process, plumose setae.

A1 (Fig. 4C): uniramous, 2-segmented; peduncle with 4 long plumose setae and 3–4 short setae at base of distal segment; distal segment with 2 thick terminal aesthetascs, 3 terminal fine plumose setae, and 2 fine subterminal aesthetascs.

A2 (Fig. 5C): basipod unchanged; endopod with increased diameter, setae reduced in number to 1 simple terminal process; scale with 11–12 plumose setae.

Mn (Fig. 6B): essentially same as earlier stages with increased complexity of denticulation.

Mxl (Fig. 7C): coxal endite with 6–7 setae; basal endite setae larger than stage II but number unchanged; endopod unchanged.

Mx2 (Fig. 8C): coxal endite proximal lobe may increase to 8 setae; scaphognathite with 7–10 plumose setae; other setal counts as in stage II.

Mxp1 (Fig. 9C): setation as in stage II.

Mxp2 (Fig. 10C): setation as in stage II.

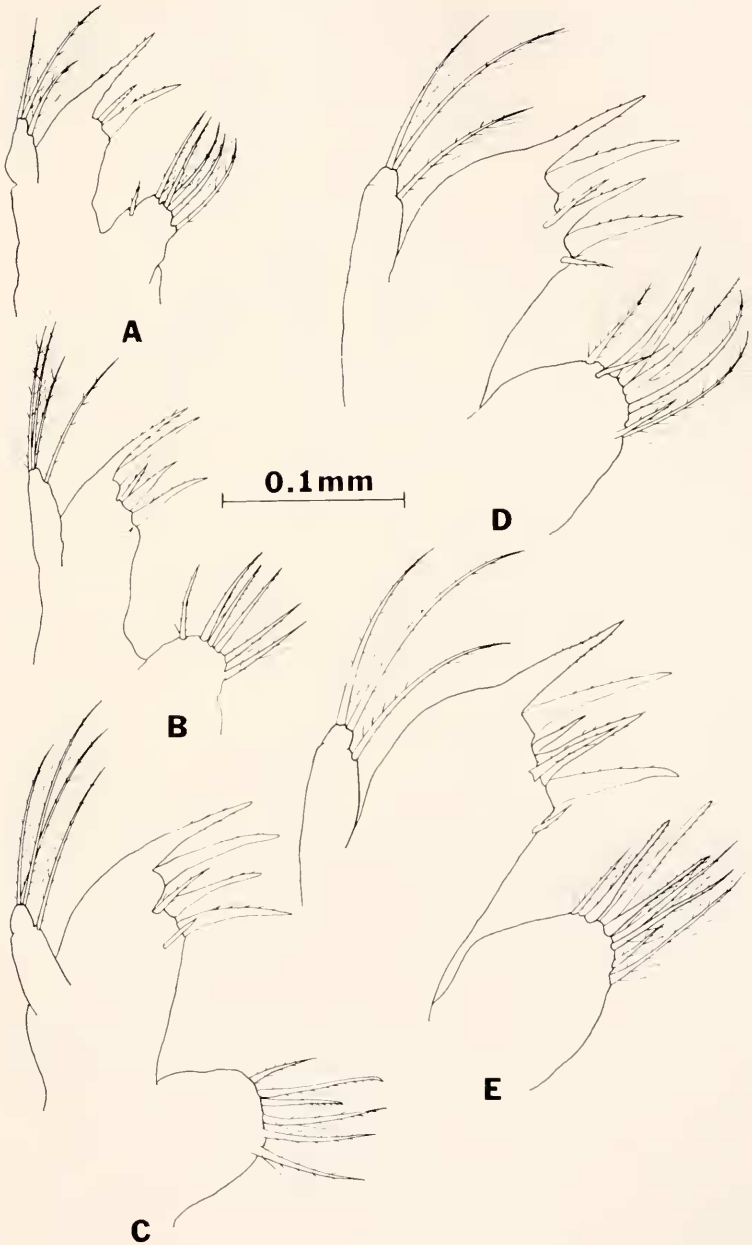

FIGURE 7. *Clibanarius vittatus:* maxillule of zoeal stage I (A), II (B), III (C), IV (D), V (E).

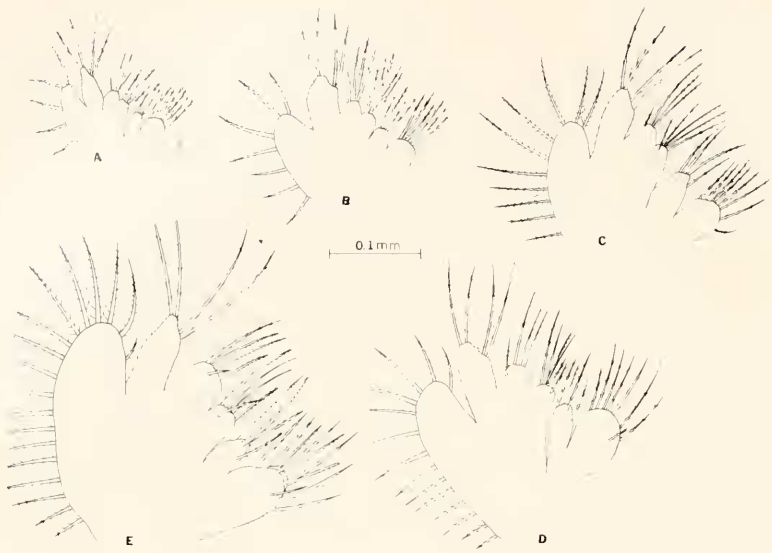

FIGURE 8. *Clibanarius vittatus*: maxilla of zoeal stage I (A), II (B), III (C), IV (D), V (E).

Mxp3 (Fig. 10c): uniramous 3-segmented with 5–6 terminal natatory plumose setae.

U (Fig. 3C): exopod fused to propod, 6–9 plumose setae present; endopod simple bud.

Zoea IV (*Fig. 1, IV, a b*)

The rostrum and carapace remain unchanged. Pleopods (P1) vary from not present (Fig. 1, IV a) to conspicuous buds (Fig. 1, IV b). Leg buds may be present. The uropod has an articulated exopod and endopod. The telson formula may be the same as stage III or increase by 1 seta to 9 + 9 (Fig. 3D). Larger individuals with well-developed leg and pleopod buds will molt directly into the megalopa.

A1 (Fig. 4D): biramous, 2-segmented; peduncle unchanged; inner ramus, plain bud up to $\frac{2}{3}$ length of outer ramus; outer ramus with 2–3 terminal aesthetases, 4 terminal setae and 2 or more fine subterminal aesthetases.

A2 (Fig. 5D): basipod unchanged; endopod longer than scale, weakly segmented with terminal process; scale with 11–14 plumose setae.

Mn: palp bud may be evident.

Mx1 (Fig. 7D): coxal endite with 7–8 setae; remaining setation as in stage III.

Mx2 (Fig. 8D): proximal lobes of coxal and basal endites may increase to 9 and 6 setae, respectively; scaphognathite with 12–14 plumose setae.

Mxp1 (Fig. 9D): setation as in stage II.

Mxp2 (Fig. 10D): endopod setation as in stage II; exopod with 6–7 terminal natatory plumose setae.

Mxp3 (Fig. 10d) : setation as in stage III.

$P1_2$ to $P1_5$: small uniramous buds variable in length.

U (Fig. 3D) : exopod and endopod articulated; exopod with 8–12 plumose setae, endopod with 3–6 setae.

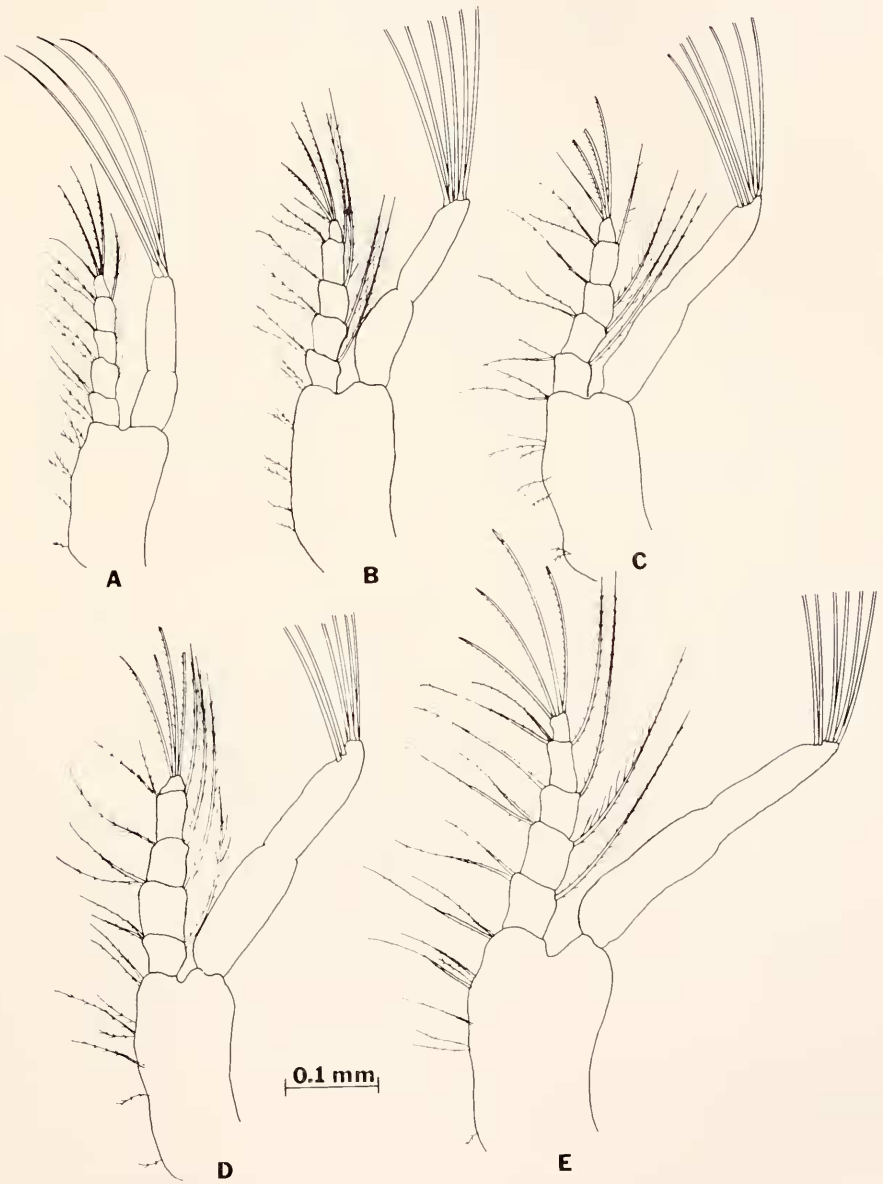

FIGURE 9. *Clibanarius vittatus:* first maxilliped of zoeal stage I (A), II (B), III (C), IV (D), V (E).

Zoea V (Fig. 1, V, 2C)

The postero-lateral carapace is somewhat expanded. Pleopod and leg buds are always well-developed and at times exhibit segmentation and some setae (pleopods with 3–4 terminal setae and leg buds with bristles). The telson is nearly rectangular with a concave posterior border (Fig. 3E). The telson formula is 9 + 9 with process types as outlined for stage III.

A1 (Fig. 4E): biramous, 2-segmented; peduncle unchanged; inner ramus

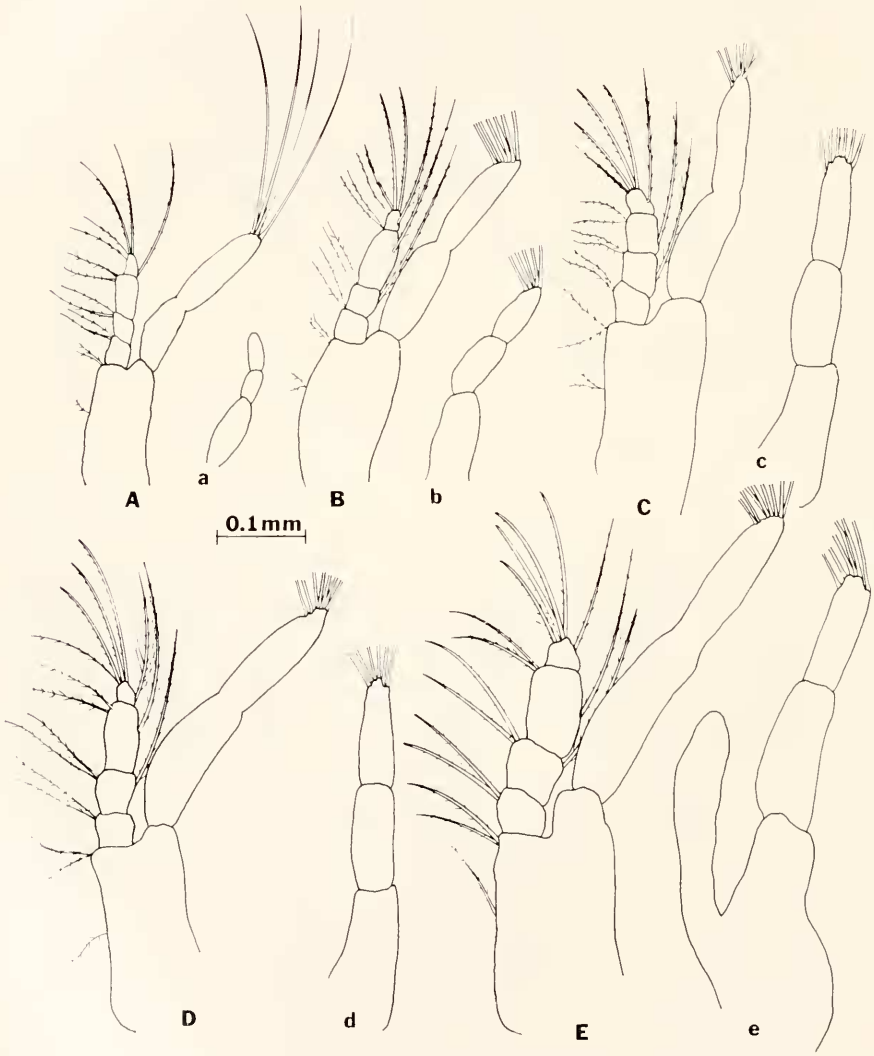

FIGURE 10. *Clibanarius vittatus:* second (A-E) and third (a-e) maxillipeds of zoeal stage I (A, a), II (B, b), III (C, c), IV (D, d), V (E, e).

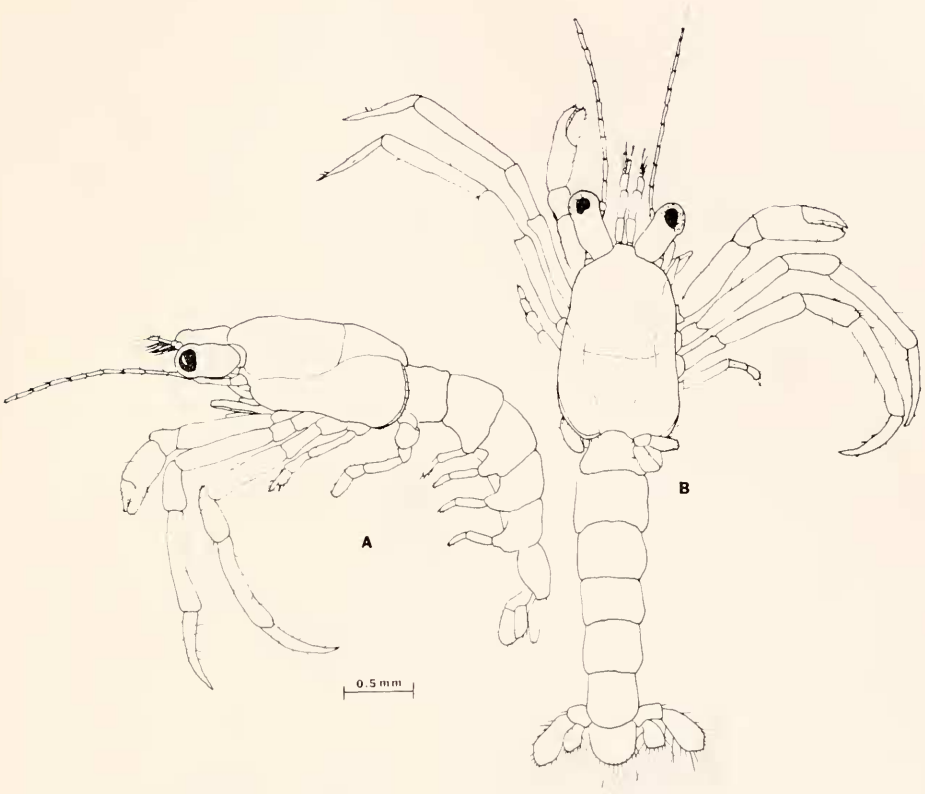

FIGURE 11. *Clibanarius vittatus:* dorsal (A) and lateral (B) views of megalopa.

may have a fine terminal hair; outer ramus with 3 terminal aesthetascs, 4 terminal setae and 4 or more subterminal aesthetascs.

A2 (Fig. 5E): basipod unchanged; endopod longer than scale, 2-segmented with terminal process; scale with 13–14 plumose setae.

Mn (Fig. 6C): simple palp present.

Mx1 (Fig. 7E): coxal endite with 8 setae; basal endite may have 1 additional small seta relative to stage IV; no change in endopod.

Mx2 (Fig. 8E): coxal endite with 9–10 setae on proximal lobe, 4 setae on distal lobe; basal endite with 5–6 setae on proximal lobe, 4–5 setae on distal lobe; endopod unchanged; scaphognathite with 15–19 plumose setae.

Mxp1 (Fig. 9E): setation as in stage II.

Mxp2 (Fig. 10E): endopod as in stage II; exopod with 8 terminal natatory plumose setae.

Mxp3 (Fig. 10e): endopod bud evident on basis; exopod with 6 terminal natatory plumose setae.

$P1_2$ to $P1_5$: long uniramous buds, at times with 3–4 terminal setae.

U (Fig. 3E): exopod and endopod articulated; exopod with 9–12 plumose setae, endopod with 5–7 plumose setae.

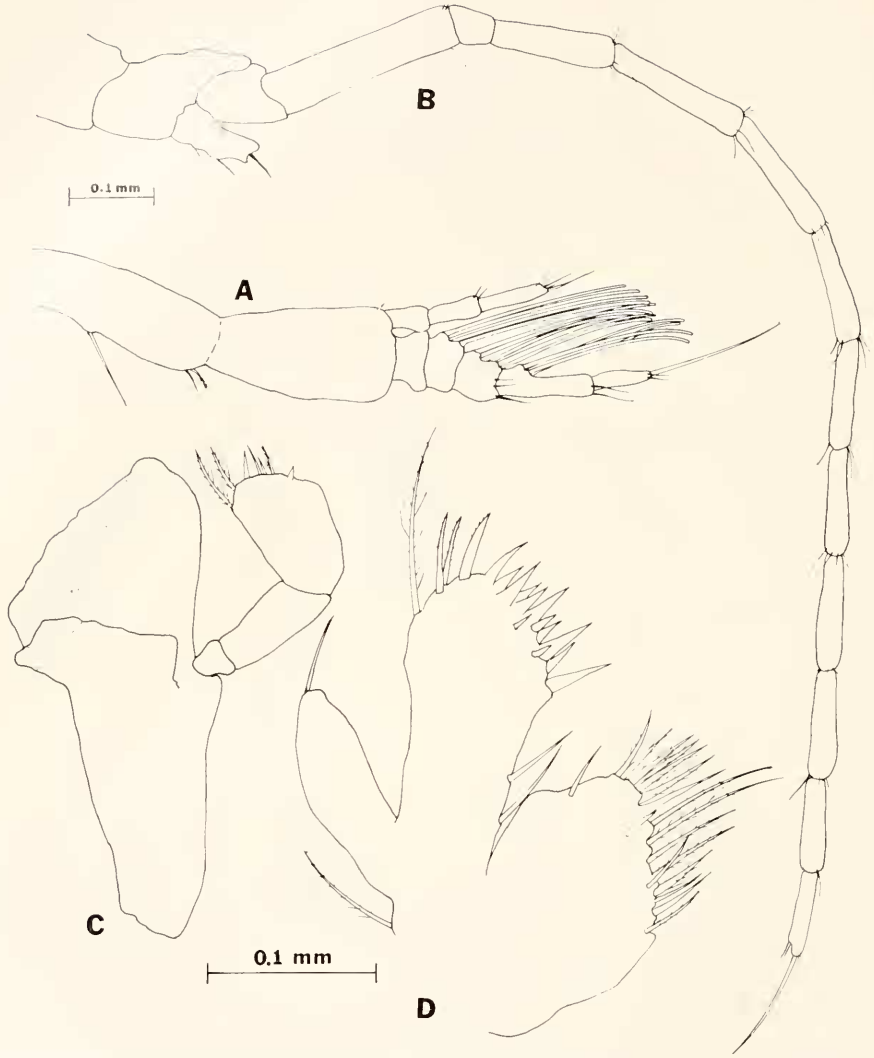

FIGURE 12. *Clibanarius vittatus;* megalopa appendages: antenna (A), antennule (B), mandible—dorsal view (C), and maxillule (D).

Megalopa (Fig. 11)

The carapace is shorter than the abdomen; the rostrum is reduced to a small blunt projection. The posterolateral carapace margin is fringed with simple setae; no spines are present. The telson (Fig. 14E) is symmetrical, the posterior margin convex with 8–9 long plumose setae and a variable number of short processes on the margin and dorsal surface. The total length of the eye and stalk is about twice the width. The cornea is slightly enlarged. No ocular scales are present.

A1 (Fig. 12A): outer ramus 5-segmented with 4 aesthetascs on segment 2, 4 aesthetascs and a few fine simple setae on segment 3, 3 aesthetascs and 2 simple setae on segment 4, and 2 subterminal simple setae and 1 long terminal simple seta on segment 5; inner ramus 3-segmented with 2 simple setae on segment 2 and 5–6 simple setae on segment 3.

A2 (Fig. 12B): flagellum with 11 segments, all with short setae distally and 1 longer seta on terminal segment tip; scale reduced with about 3 simple setae.

Mn (Fig. 12C): cuplike with prominent smooth ventral edge and short raised dorsal edge; palp 3-segmented with 2 short serrate setae and 5–7 short simple setae on terminal segment.

Mx1 (Fig. 12D): coxal endite with about 18–20 setae; basal endite with 2 subterminal setae, 16 terminal cuspidate and denticulate setae and 1 thick plumose seta; endopod unsegmented with 1 terminal simple seta and no palp; one plumose seta present on inner margin of basis.

Mx2 (Fig. 13A): coxal and basal endites bilobed with numerous setae; endopod unsegmented without setae; scaphognathite with about 60 plumose setae.

Mxp1 (Fig. 13B): bilobed basis, the proximal lobe with 5 setae, the distal lobe with about 20 setae; endopod unsegmented with 8–10 plumose setae along outer margin.

Mxp2 (Fig. 13C): basis with 3 plumose setae on inner margin, endopod 4-segmented with 4 denticulate setae on segment 3 and 6 terminal spines on segment 4; exopod with 6–8 terminal plumose setae.

Mxp3 (Fig. 13D): basis with 2–3 plumose setae on inner margin; endopod 5-segmented with complex setation; exopod with 6 long plumose setae and 2–4 short plumose setae.

P_1 to P_5 (Fig. 11, 14): chelipeds equal with setae most numerous on claws; P_1 distinctly shorter than P_2 and P_3; P_2 and P_3 similar, with dactyl about $\frac{2}{3}$ length of propodus; P_4 and P_5 shorter and subchelate with tubercles and numerous simple setae on terminal segments (Fig. 14B, C).

$P1_2$ to $P1_5$ (Fig. 14D): paired on abdominal segments 2–5; biramous, inner ramus, simple unarmed lobe, outer ramus with 8–9 plumose setae.

U (Fig. 14E): equal in size; propod with simple setae at outer margin of exopod articulation; inner margin forms raised edge at endopod articulation but no spine present; exopod with 12–20 plumose setae and about 6–7 tubercles; endopod with 8–15 plumose setae.

Discussion

The constricted tip of the rostrum and lack of spines on the carapace and abdominal somites in all stages and the deeply notched telson of stage I readily distinguish the zoeae of *C. vittatus* from pagurid larvae in South Carolina waters. However, these features are also shared by the zoeae of *C. erythropus* (Pike and Williamson, 1960b), *C. anomalus*, *C. antillensis*, *C. tricolor* (Provenzano, personal communication) and *C. zebra* (Hazlett, personal communication). Therefore, in regions where more than one species of *Clibanarius* are present, additional features will be required to separate species.

Staging of zoeae I–IV for *C. vittatus* may be accomplished using maxilliped setation and telson/uropod characters as outlined by Pike and Williamson (1960b). The separation of stage IV and V is more difficult since the maxillipeds, telsons,

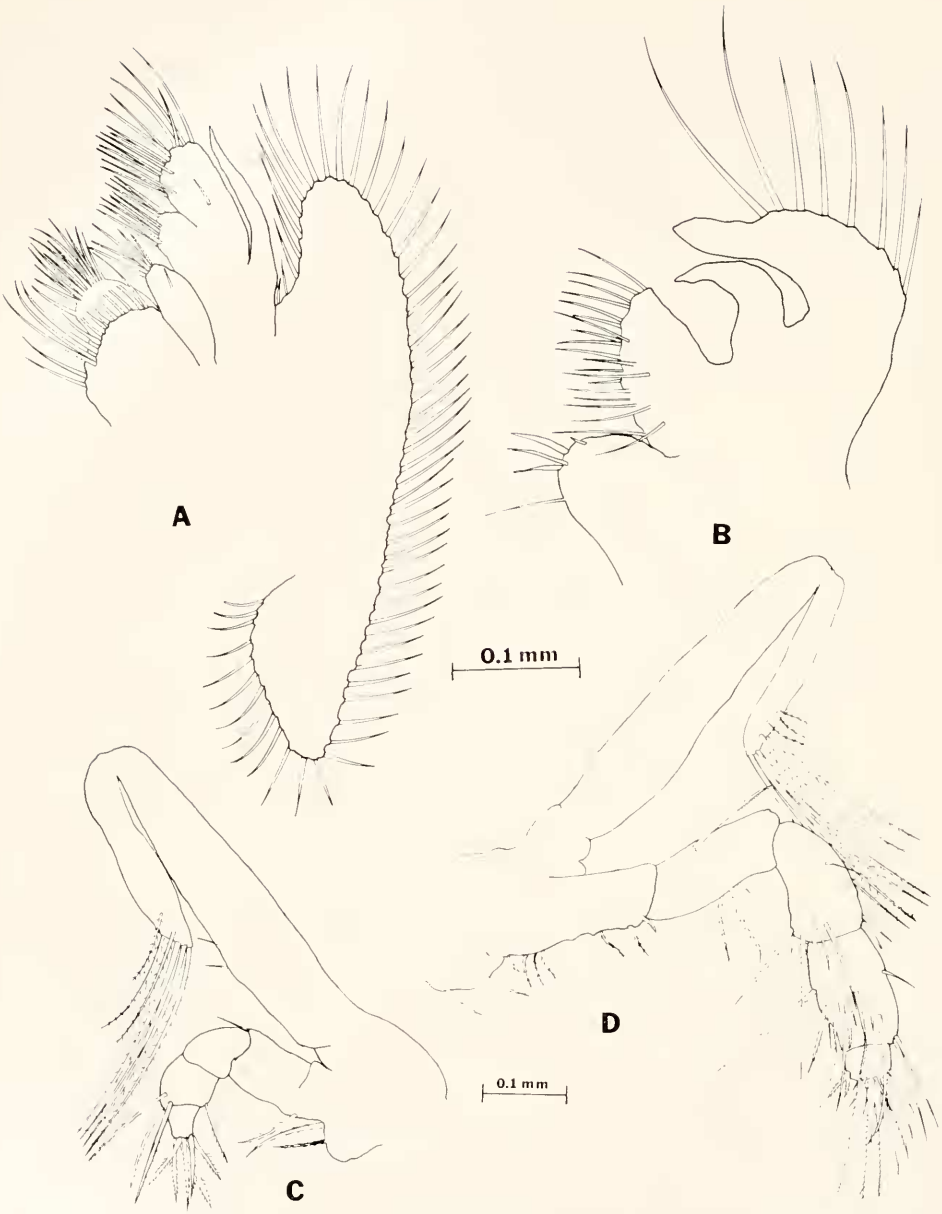

FIGURE 13. *Clibanarius vittatus,* megalopa appendages: maxilla (A), first maxilliped (B), second maxilliped (C), and third maxilliped (D).

and uropods are nearly identical in the two stages. Pike and Williamson (1960b) note the presence of pleopods in stage V diogenid larvae as opposed to their absence in stage IV. In *C. vittatus,* pleopods may be present in both stages

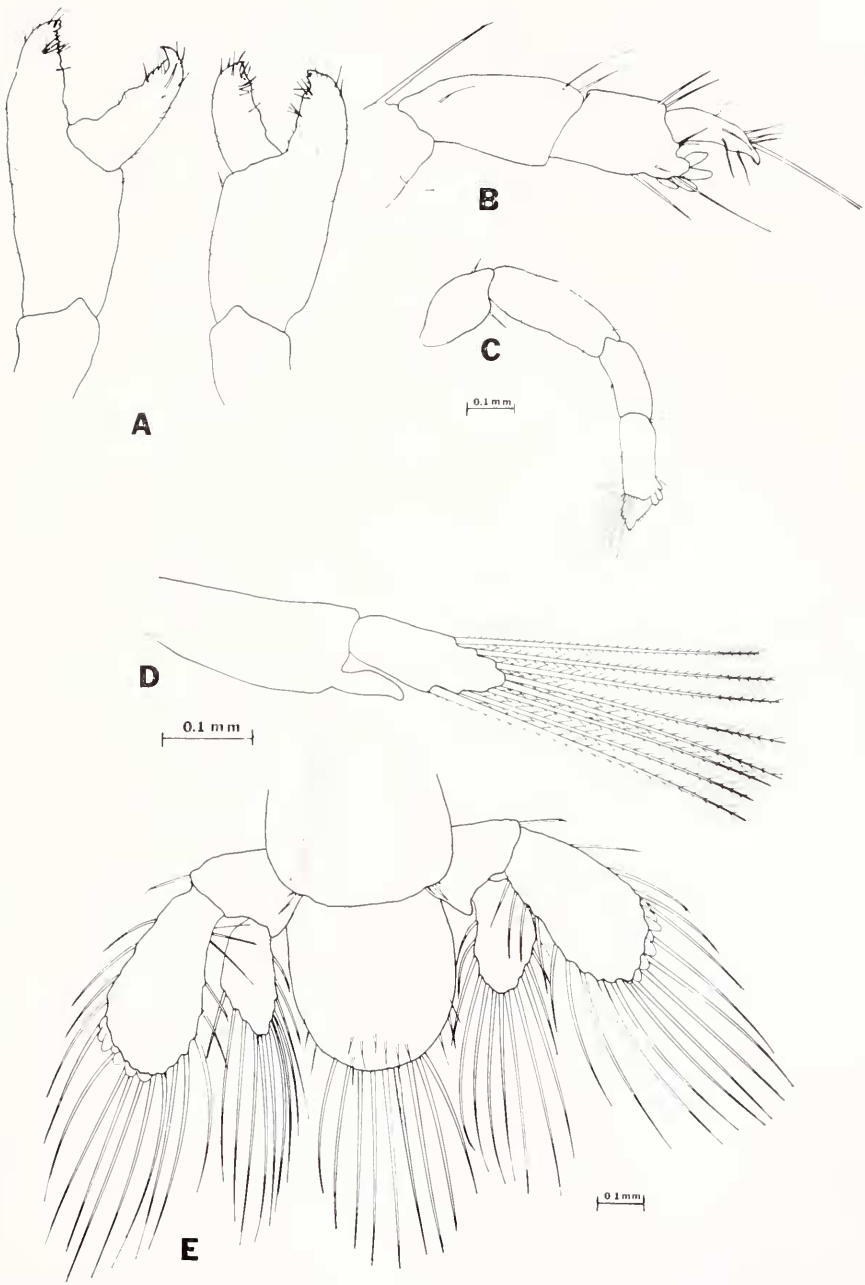

FIGURE. 14. *Clibanarius vittatus*, megalopa appendages: right and left chelipeds (A) fourth pereiopod (C), fourth pleopod (D), and telson (E).

although less common in stage IV. The most reliable single characteristic to separate stages IV and V in *C. vittatus* is the lack of mandibular palps in stage IV.

The most common developmental series for *C. vittatus* is five zoeal stages. A short series of four zoeal stages was observed eight times in the present study and also noted by Kircher (1967). The number of zoeal stages for the Diogenidae is variable, ranging from two zoeae in *Paguristes sericeus* (Rice and Provenzano, 1965) to 6–8 zoeae in *Calcinus tibicen* (Provenzano, 1962).

Available characteristics of diogenid larvae have been reviewed by Provenzano (1968). The constricted rostrum and lack of abdominal spines may prove to be characteristic for the genus *Clibanarius,* but larvae of only two species have been described in detail to date. In *C. erythropus* (Pike and Williamson, 1960b) the telson and sixth abdominal somite are first articulate in stage II, as opposed to stage III in *C. vittatus.* In stage III larvae the fourth telson process is reduced to a small tubercle in *C. erythropus,* while the process is retained as a prominent fused spine in *C. vittatus.* Ranges of setation counts also vary in some appendages, but, in general, the zoeae of the two species are very similar.

The megalopa of *C. vittatus* may be recognized in plankton samples from South Carolina by its equal-sized chelipeds and suboval telson with nine long marginal setae. The second and third pereiopods are nearly identical. Distinctive spines or teeth on the dactyl or propodus, as seen in certain other diogenid larvae (Provenzano, 1968), are absent.

As the only other megalopa described for the genus is that of *C. erythropus* (Dechancé and Forest, 1958), a detailed discussion of generic and specific characteristics is impossible at present. However, based on key morphological characteristics of the megalopa listed by Provenzano (1968), certain points should be noted. The ventral antennular ramus is three-segmented in *C. vittatus, C. erythropus,* and *C. tricolor* (Provenzano, 1968). The slightly dilated cornea, lack of eye scales, carapace shape, uropods, and telson are all similar in *C. vittatus* and *C. erythropus.* The flagellum of the antenna consists of eleven segments in *C. vittatus,* while there are only seven segments in *C. erythropus* and *C. tricolor.* The endopod tip in the megalopa of *C. erythropus* is distinctly recurved (Dechancé and Forest, 1958); in the megalopa of *C. vittatus* it is straight and very similar to that described for *Petrochirus diogenes* (Provenzano, 1968).

Despite unexplained differences in stage duration and mortality, the morphology of the two hatches of *C. vittatus* larvae reared in this laboratory varied little from each other. Major morphological features were consistant while setal counts varied within similar ranges. Plankton tows from North Inlet yielded only stage I zoeae, making planned comparisons with "wild" larvae impossible. In general, descriptions of laboratory reared decapod larvae appear adequate to identify and usually stage "wild" larvae but detailed comparisons are rare and should be pursued.

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Summary

1. A table of previous descriptions of larvae of Diogenidae is given.

2. Larvae of the hermit crab *Clibanarius vittatus* were reared on a diet of *Artemia* nauplii. Five, rarely four, zoeal stages and a megalopa were obtained. Duration, mortality and sizes of larvae from two hatches are listed.

3. Detailed descriptions and figures for each larval stage are presented.

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